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**SEISMIC REFRACTION INVESTIGATIONS  
PISCATAQUA RIVER SHIP CHANNEL  
KITTERY, MAINE AND PORTSMOUTH, NEW HAMPSHIRE**

**Prepared For:** Department of the Army  
Corps of Engineers  
New England Division  
Waltham, Massachusetts

**File 7760  
January 17, 1978**

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1.00 INTRODUCTION

This report presents the results of marine seismic refraction investigations in the Piscataqua River near Kittery, Maine and Portsmouth, New Hampshire. The purpose of the effort was to determine the character and depths of materials below the River bottom as an aid to classifying materials that will have to be excavated in a channel widening project. Two specific areas were investigated: One area on the northeasterly side of the ship channel between Memorial Bridge and the New Hampshire and Maine Bridge over the Piscataqua River and another area on the southerly side of the channel north of Goat Island.

The investigation was conducted by S.A. Alsup & Associates of Waban, Massachusetts for the New England Division of the Department of the Army Corps of Engineers. Field investigations were made on December 12, 13, and 14 of 1977 with subsequent data analysis and interpretations forming the basis of this report. Engineering location control was provided by Town Planning and Engineering Associates, Inc. of Portsmouth, New Hampshire, explosives and licensed blasting personnel were assigned by Explosives Engineering, Inc. of Shirley, Massachusetts, and the field effort was conducted from a vessel owned and operated by Mr. Elmer Richardson of Kittery Maine. Personnel, materials, and marine vessel were supplied as subcontracts to S.A. Alsup & Associates.

Some 13,615 linear feet of marine seismic refraction profiles

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are reported below as a result of the investigation. Areas investigated are shown in Figures 1 and 2, with shot points (small black dots) indicated along each of the continuous profile alignments. These alignments cover the areas indicated by the Corps of Engineers as being of interest: Some additional profile data were obtained during the field operations, but only the general conditions outside the areas of interest to the Corps of Engineers are displayed in the resulting profiles.

Unfavorable field conditions were commonplace during the field investigation phase of the effort, including strong winds, freezing rain and snow, extreme high tides, and low ambient air temperatures. Approximately 15% of the field data were unuseable because of low temperature effects on development of photographic data charts and vessel-hydrophone alignment problems. The remainder of data is of good quality, and the results are expected to be reliable within the usual limitations for marine refraction data.

## 2.00 METHOD OF INVESTIGATION

This investigation was performed using a 12-element hydrophone string suspended two feet below water surface with 20-foot spacing between hydrophones. Small dynamite charges initiated by electric caps ( $\frac{1}{4}$ -lb 40% gel w/instant caps) were used as an energy source in the first part of the field survey. Pre-formed "boosters" were used instead of dynamite during the last two days of field investigation. Procedures in the field data collection include:

- 1) Align vessel with transit control from selected positions on the New Hampshire & Maine Bridge while proceeding up-current with the hydrophone string trailing over the alignment. Nine positions corresponding to the nine alignments shown on Figure 1 were established prior to profiling. Point "SHAW" and three positions on Pierce Island (west of survey area, not shown) were used for the investigation area shown in Figure 2.

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- 2) Drop weighted explosive charge to bottom, note water depth from fathometer, signal second transit position for azimuthal location control, move boat forward to place charge 50-feet from boat, note time-of-day.
- 3) Detonate charge and record hydroacoustic response from all hydrophones simultaneously.
- 4) Repeat Steps 1 through 3 above to continue profiling.

These procedures permit collection of the data needed to correct position and elevation parameters during the data reduction effort. Shot points were located by knowing the lateral position of the boat at charge-drop time from the aligning transit position, and the position along the alignment is determined from the measured angle referenced to baseline between the two transit positions. Water depth is measured directly from the fathometer, with correction to Mean Low Water Datum ("mlw" on the profiles shown below) from time-of-day and tidal charts. Depths were also checked by comparison of fathometer-position readings with bottom depths shown in maps of the area provided by the Corps of Engineers. Additional location notes were taken with regard to shoreline and marine features during the field investigation.

All alignments shown were investigated with "reversed-profiling" to the extent possible under existing tidal conditions. Line 12 (Figure 2) was not reversed because of the heavy concentration of lobster pots and small boat moorings in the area east of the Line 12 locale. These features also prevented further profiling to the east of Line 12. Complex river flow and tidal currents also prevented profiling in the area westerly of Line 5 (Figure 1) because a linear hydrophone string could not be established in that area under existing conditions.

The profiling reported here includes individual refraction profiles from the 176 shot points indicated in Figures 1 and 2.

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### 3.00 DATA ANALYSIS

All data for this report were analyzed according to standard "cross-over distance" refraction procedures where the pattern of first arriving acoustic waves is plotted on a time-distance graph and distance to changes in slope in the pattern are used to calculate depth to major changes in velocity beneath the refraction spread (hydrophone string). Refraction velocities in the different materials beneath the spread are measured directly from the plotted data. Depth calculations using the velocities and cross-over distance are standard formulations.

Several corrections are required to make the calculated depths accurate and referenced to Mean Low Water as a datum:

- 1) add to calculated depth from plotted data:

charge depth  
hydrophone string depth

- 2) subtract from calculated depth:

tidal elevation above mlw

- 3) correct for distance between first hydrophone and shot point according to water depth (a fixed boat to shot distance of 50-feet is used for this particular investigation, with first hydrophone 60-feet from the stern of the boat).

IT IS IMPORTANT TO NOTE IN THIS SURVEY THAT STRONG EASTERLY STORM WINDS WERE ACTIVE ON THE SEACOAST AND MAXIMUM HIGH TIDES WERE PRESENT AT TIME OF SURVEY IN THE FIELD INVESTIGATION. LOCAL SOURCES INDICATE THAT ACTUAL TIDES MAY BE SEVERAL FEET HIGHER THAN TIDAL CHARTS STATE UNDER SUCH CONDITIONS. CORRECTIONS WERE MADE ON THE BASIS OF MAXIMUM HIGH TIDE (11 to 12 feet) IN PRESENTING THE REFRACTION PROFILES, AND AN ERROR MAY BE PRESENT DUE TO THIS EFFECT. ELEVATIONS SHOWN WILL BE TOO SHALLOW (HIGHER) THAN ACTUAL IF THIS ERROR IS PRESENT.

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#### 4.00 INTERPRETATION

Interpretation of the seismic refraction data beyond the depth and velocity information obtained above includes general relationships between the different geological elements of the area in terms of bulk density of the materials and the effects of bulk density upon seismic velocities. Identification of rock types or the character of other deposits from the seismic data is done on the basis of increasing seismic velocity with increasing bulk density, supported by experience showing types of materials encountered in areas where prior seismic investigations have been made. For this particular investigation, the following relationships are expected:

<u>Refraction Velocity</u> (feet/second)	<u>Materials Indicated</u>
4800-5400	Soft, unconsolidated sediments of silts, sands, and clays. Fully water saturated and readily excavated.
6200-9600	Moderately hard to hard glacial till, including clay, silt, sand, gravel, and possibly boulders. May include some deeply weathered bedrock. Moderately difficult to difficult to excavate, may require explosives in upper part of velocity range.
13200-17200	Hard, dense, and competent bedrock, expected to be gneiss and schist. Will require explosives for excavation except in a few isolated weathered zones.

The calculations referenced in Section 3.00 provide depth and velocity information that are plotted directly beneath the

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shot point according to standard procedures. Zones and layers of differing geologic types (differing velocities) are then delineated by smoothed line extensions between the calculated conditions at each shot point.

### 5.00 RESULTS

Results of the marine seismic refraction profiling are shown in Figures 3 through 12 for the area investigated between the Memorial and New Hampshire & Maine Bridges. Profiles for the area north of Goat Island are shown in Figures 13 through 15. Average seismic refraction velocities are shown in the figures along with the generalized interpretation as described above.

The "between-bridge" area is typified by a layer of soft sediments over either glacial till or bedrock in the onshore part, with the soft sediment layer generally less thick and finally absent proceeding from the onshore area toward the ship channel. Glacial till appears in patches toward the central parts of the refraction alignments, with bedrock exposed on the bottom in the northerly through westerly through southerly directions around Badger's Island and along the sides and bottom areas of the ship channel.

Profiling in the Goat Island area shows bedrock at bottom in the westerly part of the area investigated, but a thick cover of glacial is indicated in the easterly part. Separation of these two conditions is approximately at a northeasterly line extending from the northeasternmost point on Goat Island. No significant deposits of soft unconsolidated materials are indicated by the seismic refraction data in any part of this area.

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## 6.00 RECOMMENDATIONS

Several confirmatory borings are recommended to assure that no conditions exist that could interfere with the standard refraction profiling techniques and analytical procedures, and to check for errors caused by the tidal conditions. Primary locations for such borings are:

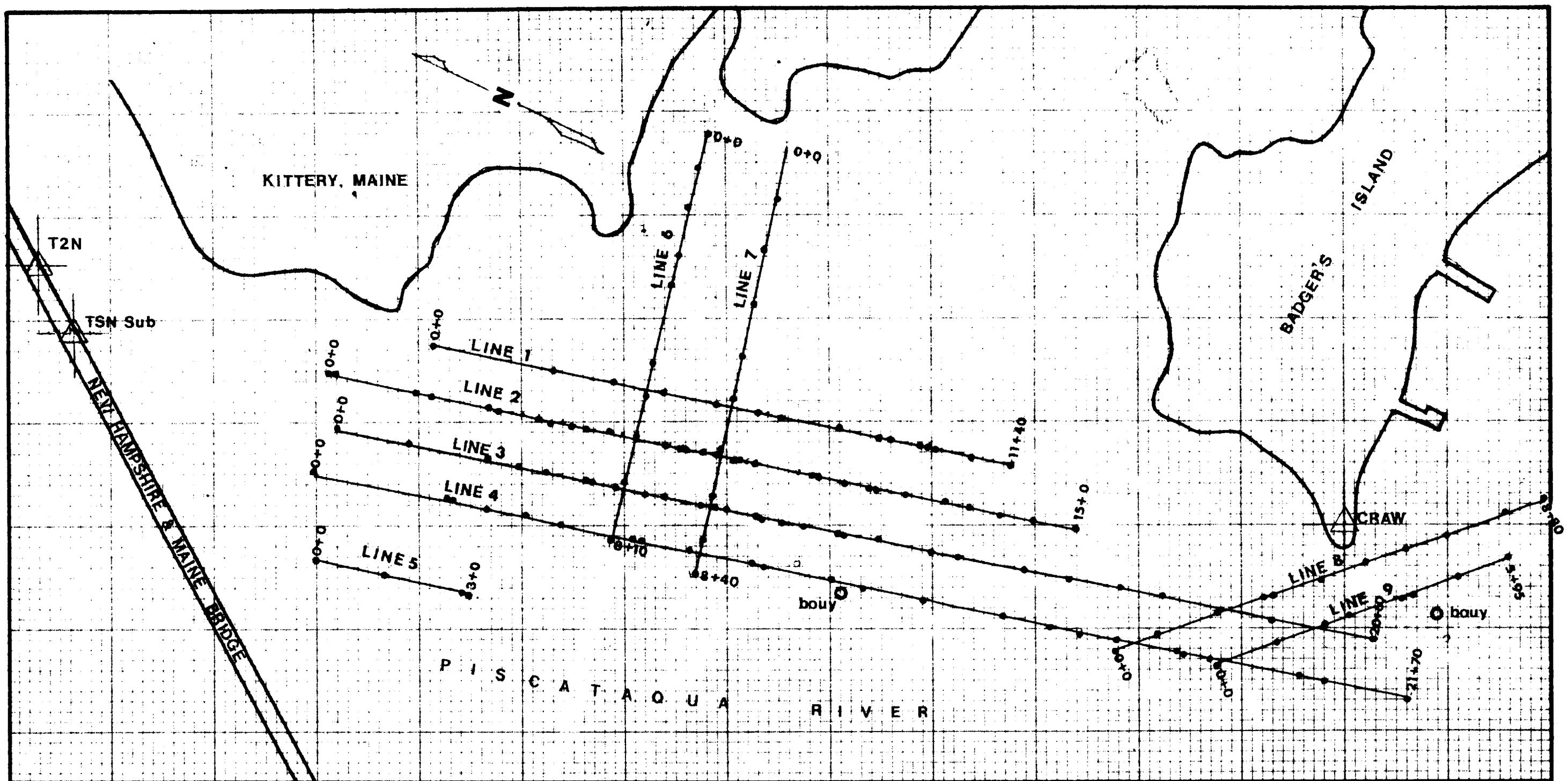
- 1) in the rectangular area enclosed by Lines 1, 2, 6, and 7.
- 2) between Lines 10 and 11 on a line between benchmarks "PRISON" and "SHAW".

Additional borings may also be taken:

- 3) at the intersection of Line 3 and Line 7.
- 4) between Lines 3 and 4, due east of the buoy northwesterly from Badger's Island.
- 5) in the area northerly and easterly from Goat Island where profiling could not be conducted.

These borings will also provide information about the presence or absence of any soft layers that are "transparent" to the acoustic signals (i.e., insufficient density contrast to cause reflection or refraction of the acoustical energy).

(END)



INTERFACES OR INFERRED INTERFACES BETWEEN SEISMIC VELOCITY ZONES ON THE FIGURES ABOVE ARE BASED UPON THE RESULTS OF STANDARD GEOPHYSICAL INTERPRETATION TECHNIQUES. DEPTHS BELOW SURFACE, VELOCITY ZONE THICKNESS, AND VELOCITIES ARE INDICATIVE OF AVERAGE CONDITIONS BENEATH THE GEOPHONE SPREAD AND SHOULD BE USED FOR PLANNING PURPOSES ONLY. ESTIMATED ACCURACY OF THICKNESSES AND DEPTHS FOR THIS SURVEY IS \_\_\_\_\_. DEPTHS TO INFERRED SATURATED ZONES APPLY TO DEPTHS AT TIME OF SURVEY.

SCALE: VERTICAL 1" = 200'  
HORIZONTAL

SHOT POINTS —————— 1600  
GEOPHONE SPREAD —————— 4700  
INFERRED SUBSURFACE VELOCITY BOUNDARIES —————— 10200  
SEISMIC WAVE VELOCITIES IN FEET PER SECOND

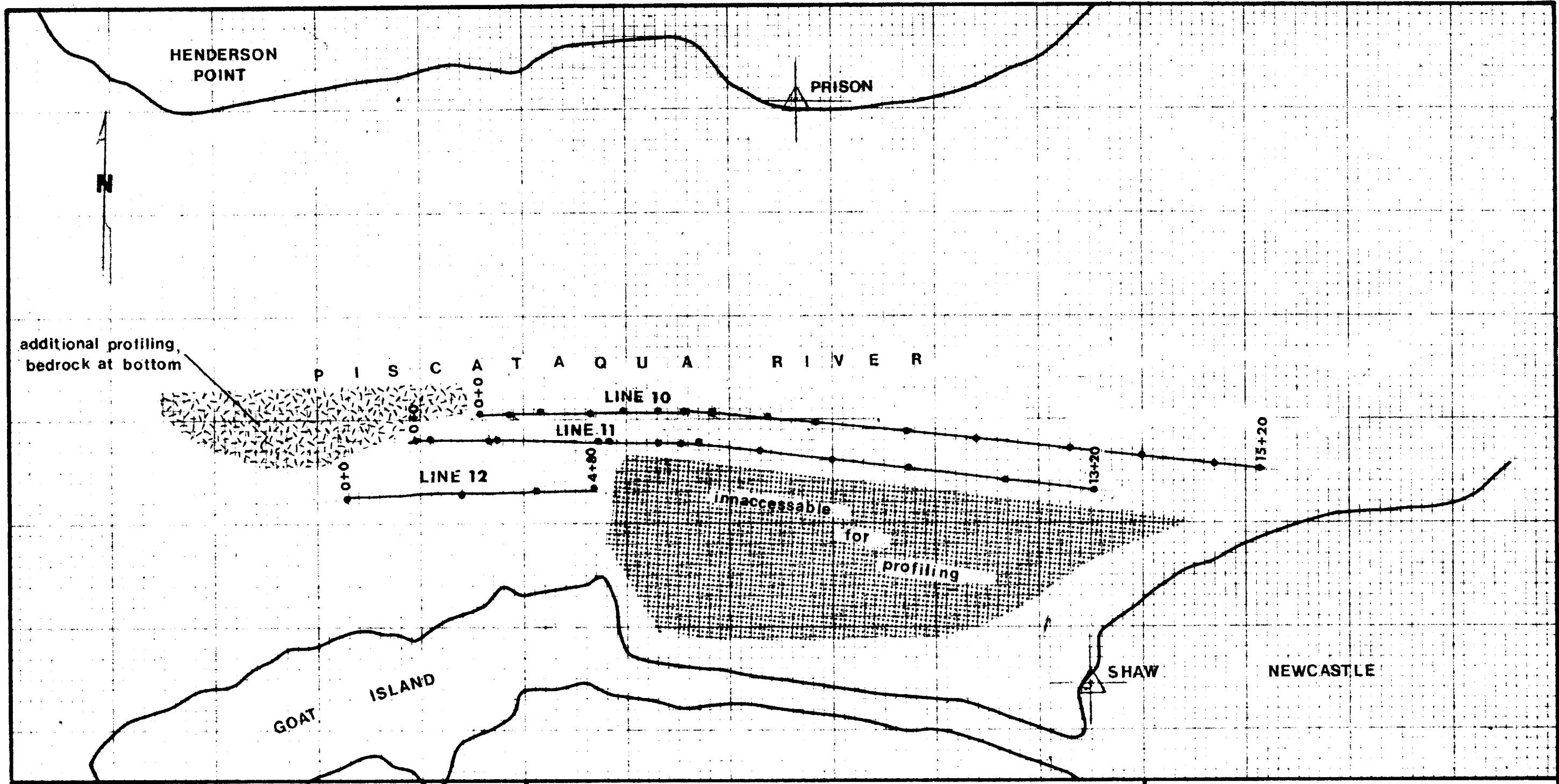
### Piscataqua River

SEISMIC SURVEY PROFILES  
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FIGURE 1



INTERFACES OR INFERRED INTERFACES BETWEEN SEISMIC VELOCITY ZONES ON THE FIGURES ABOVE ARE BASED UPON THE RESULTS OF STANDARD GEOPHYSICAL INTERPRETATION TECHNIQUES. DEPTHS BELOW SURFACE, VELOCITY ZONE THICKNESS, AND VELOCITIES ARE INDICATIVE OF AVERAGE CONDITIONS BENEATH THE GEOPHONE SPREAD AND SHOULD BE USED FOR PLANNING PURPOSES ONLY. ESTIMATED ACCURACY OF THICKNESSES AND DEPTHS FOR THIS SURVEY IS \_\_\_\_\_. DEPTHS TO INFERRED SATURATED ZONES APPLY TO DEPTHS AT TIME OF SURVEY.

SCALE: VERTICAL 1"=200'  
HORIZONTAL

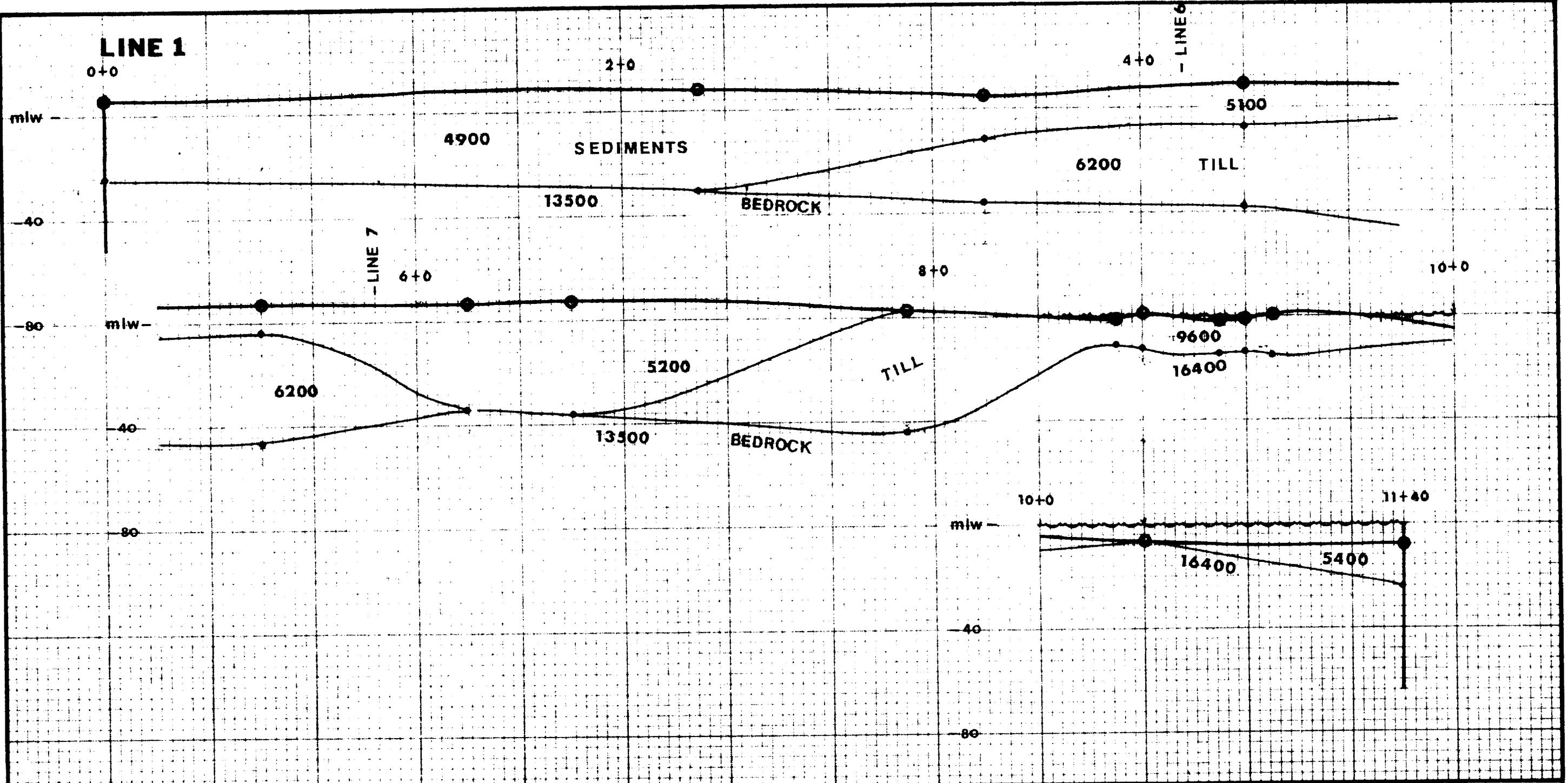
SHOT POINTS ————— 1600  
GEOPHONE SPREAD ————— 4700  
INFERRED SUBSURFACE VELOCITY BOUNDARIES ————— 10200  
SEISMIC WAVE VELOCITIES IN FEET PER SECOND

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SCALE: VERTICAL 1"-40'  
HORIZONTAL

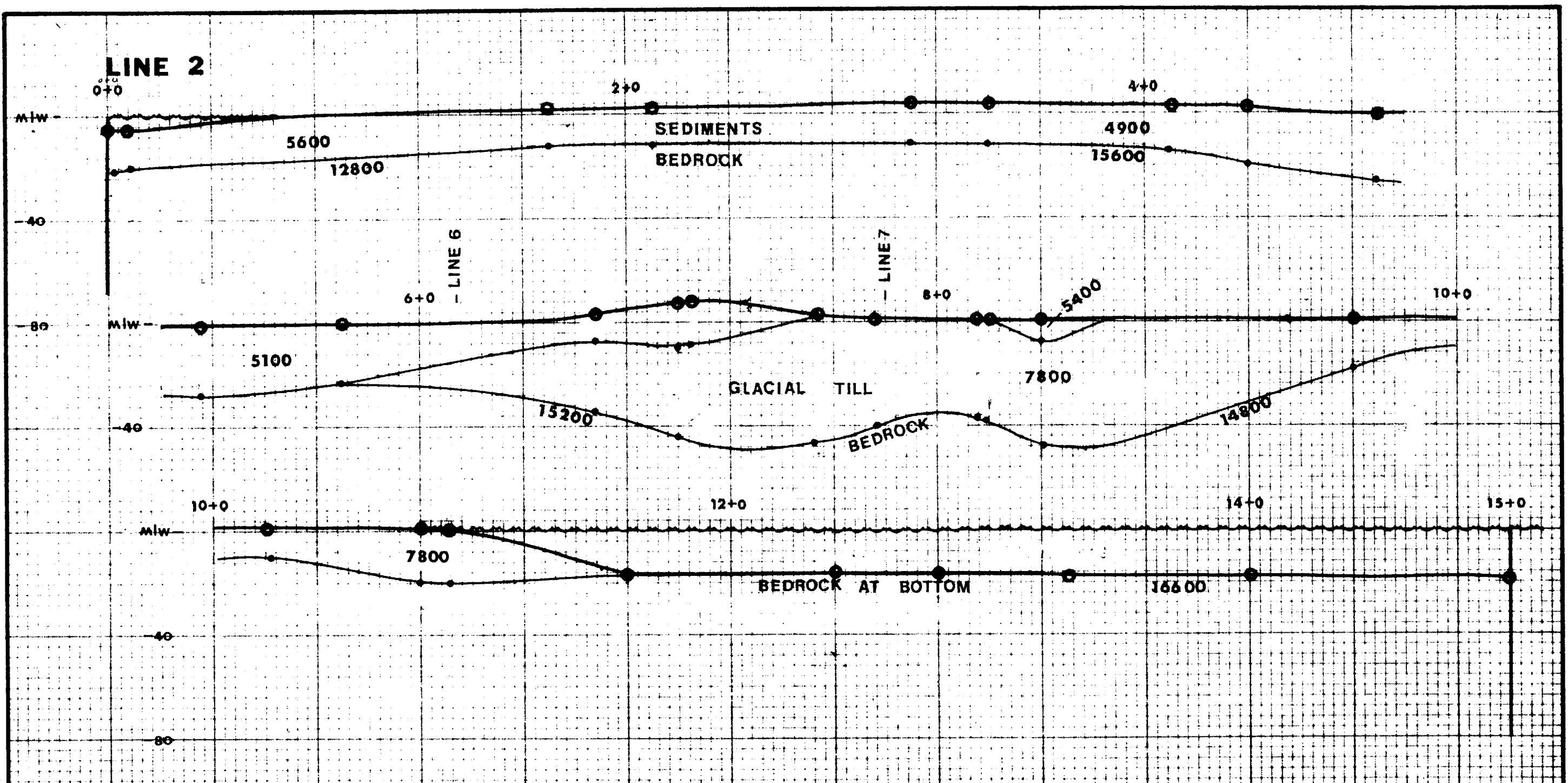
SHOT POINTS ————— 1600  
GEOPHONE SPREAD ————— 4700  
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SCALE: VERTICAL 1" = 40'  
HORIZONTAL

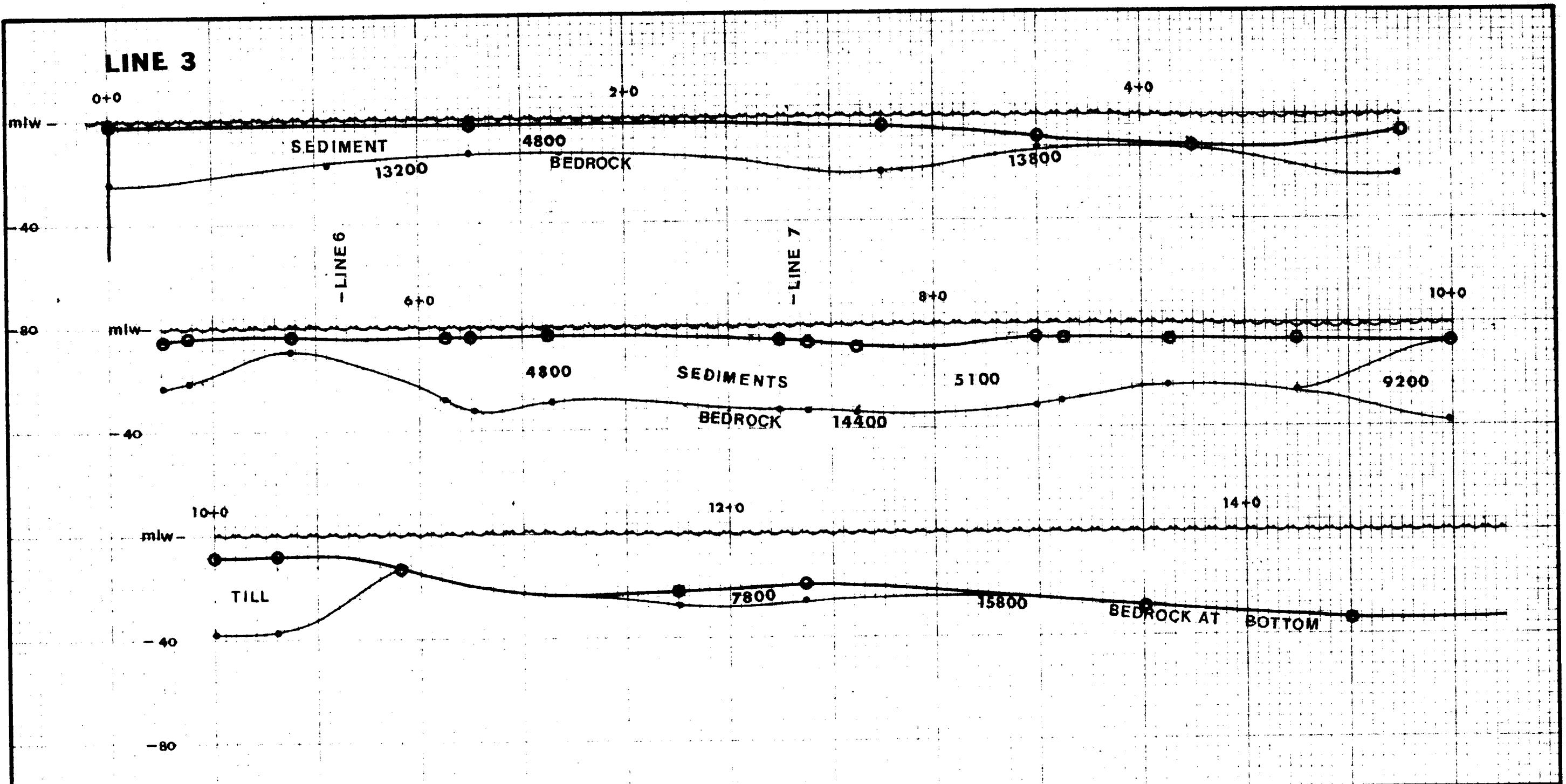
SHOT POINTS —————— 1600  
GEOPHONE SPREAD —————— 4700  
INFERRED SUBSURFACE  
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SCALE: VERTICAL 1" = 40'  
HORIZONTAL  
SHOT POINTS ——————  
GEOPHONE SPREAD ——————  
INFERRED SUBSURFACE VELOCITY BOUNDARIES ——————  
SEISMIC WAVE VELOCITIES ——————  
IN FEET PER SECOND

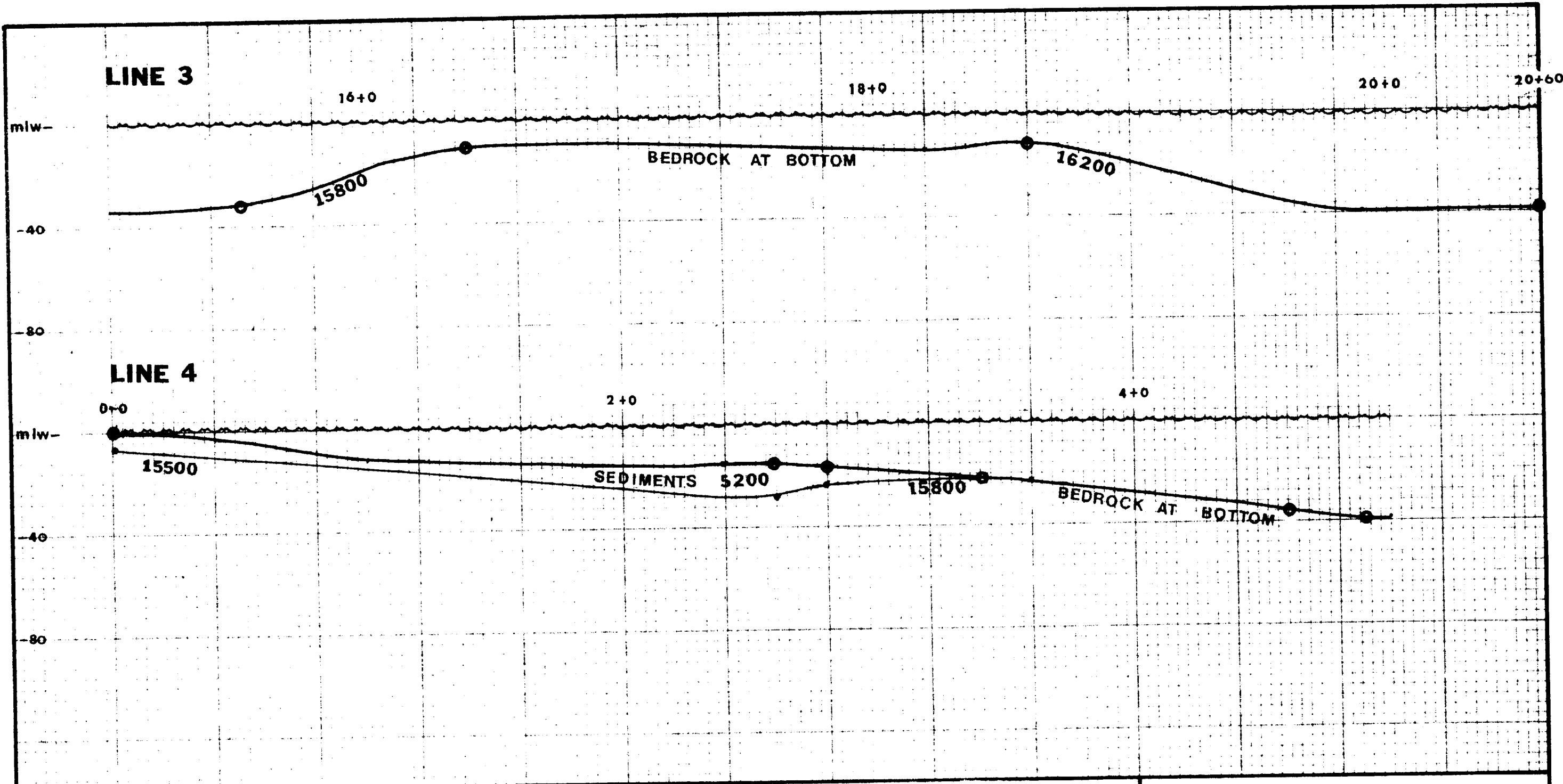
1600  
4700  
10200

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HORIZONTAL

SHOT POINTS ————— 1600

GEOPHONE SPREAD ————— 4700

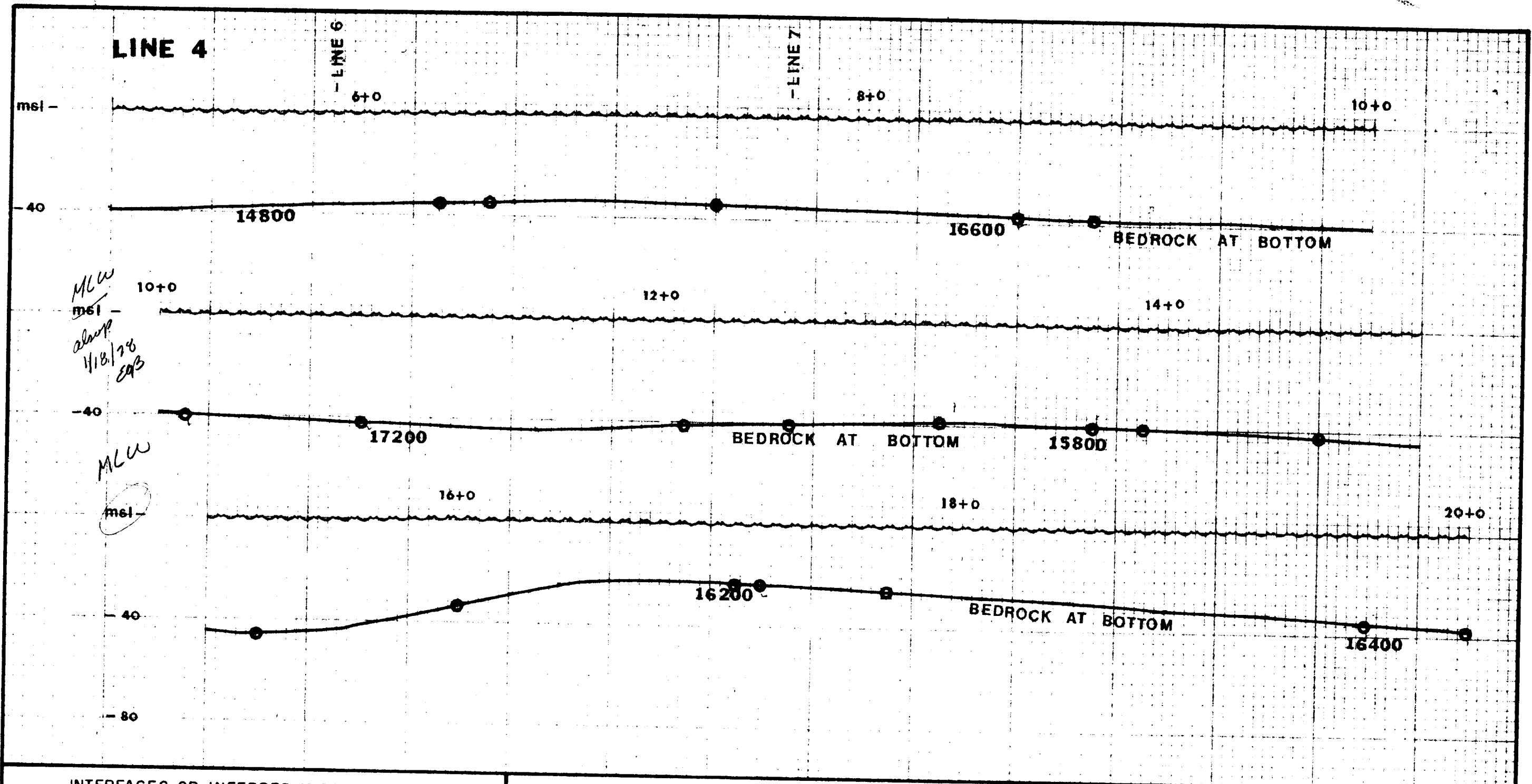
INFERRED SUBSURFACE  
VELOCITY BOUNDARIES ————— 10200

SEISMIC WAVE VELOCITIES  
IN FEET PER SECOND

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GEOPHONE SPREAD

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INFERRED SUBSURFACE  
VELOCITY BOUNDARIES

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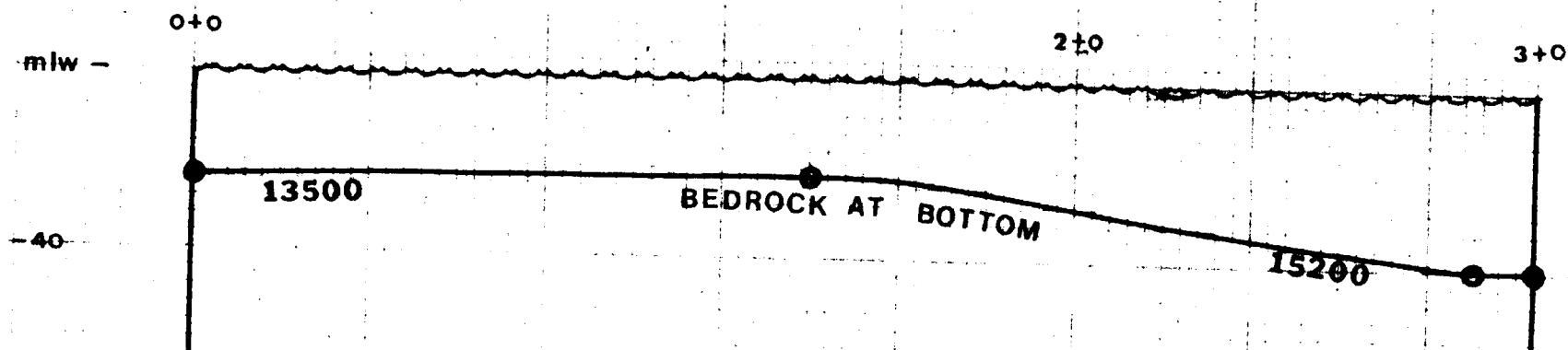
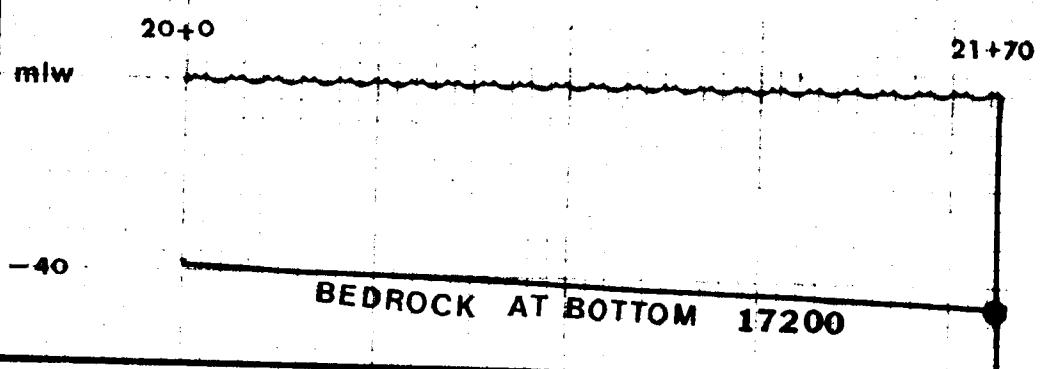
SEISMIC WAVE VELOCITIES  
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**LINE 5****LINE 4**

INTERFACES OR INFERRED INTERFACES BETWEEN SEISMIC VELOCITY ZONES ON THE FIGURES ABOVE ARE BASED UPON THE RESULTS OF STANDARD GEO-PHYSICAL INTERPRETATION TECHNIQUES. DEPTHS BELOW SURFACE, VELOCITY ZONE THICKNESS, AND VELOCITIES ARE INDICATIVE OF AVERAGE CONDITIONS BENEATH THE GEOPHONE SPREAD AND SHOULD BE USED FOR PLANNING PURPOSES ONLY. ESTIMATED ACCURACY OF THICKNESSES AND DEPTHS FOR THIS SURVEY IS  $\pm 10\%$ . DEPTHS TO INFERRED SATURATED ZONES APPLY TO DEPTHS AT TIME OF SURVEY.

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HORIZONTAL

SHOT POINTS

1600

GEOPHONE SPREAD

4700

INFERRED SUBSURFACE  
VELOCITY BOUNDARIES

10200

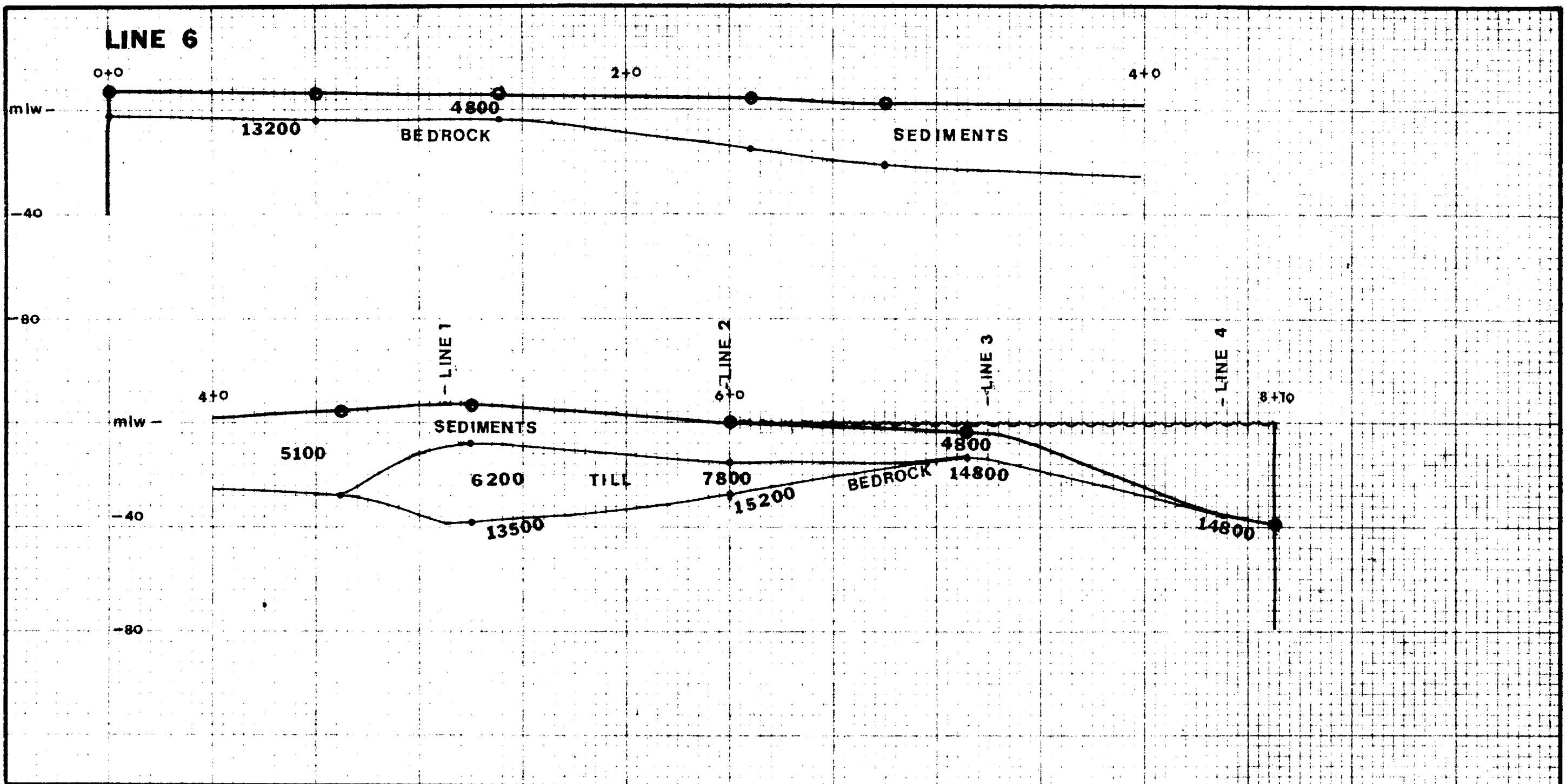
SEISMIC WAVE VELOCITIES  
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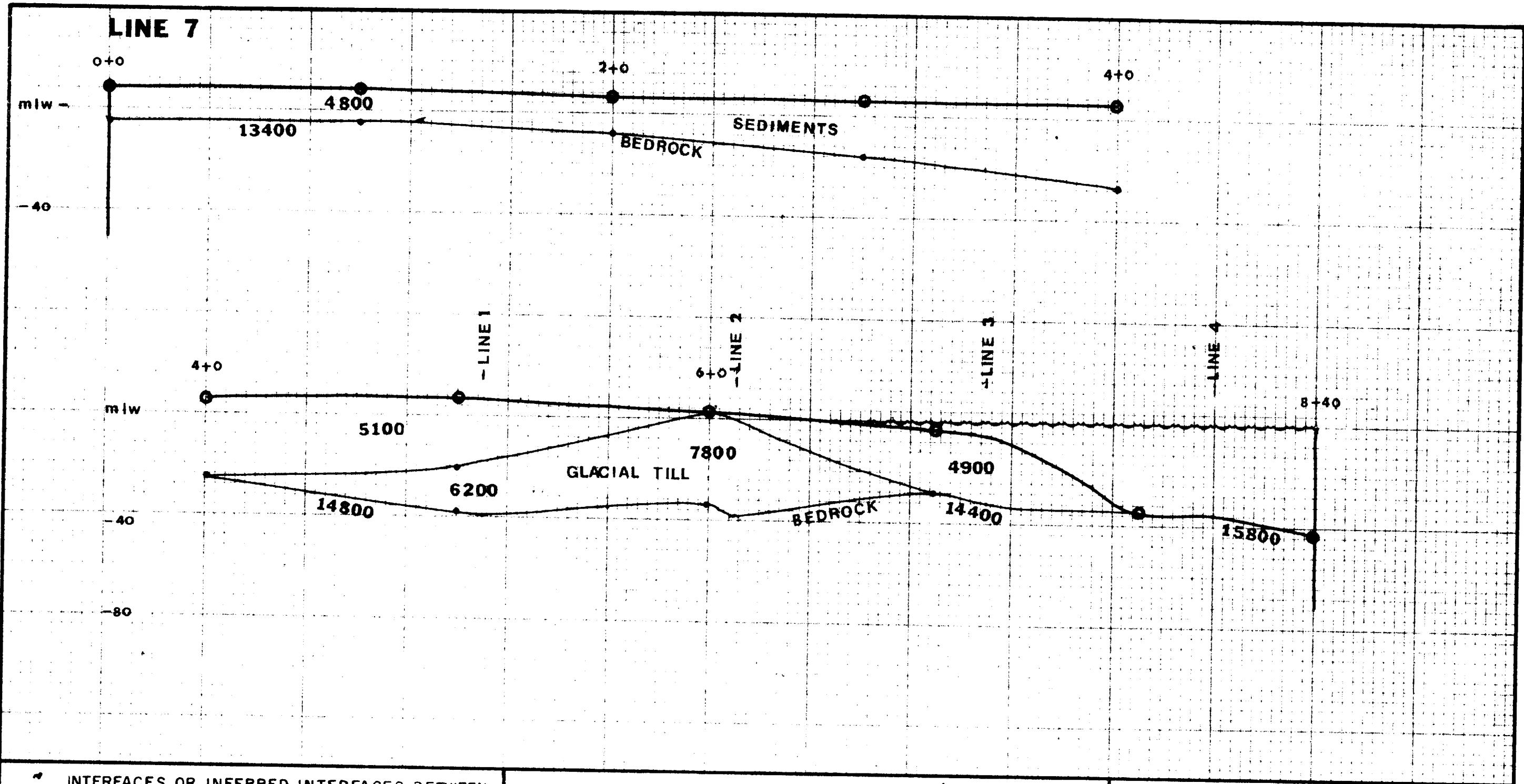
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SEISMIC WAVE VELOCITIES

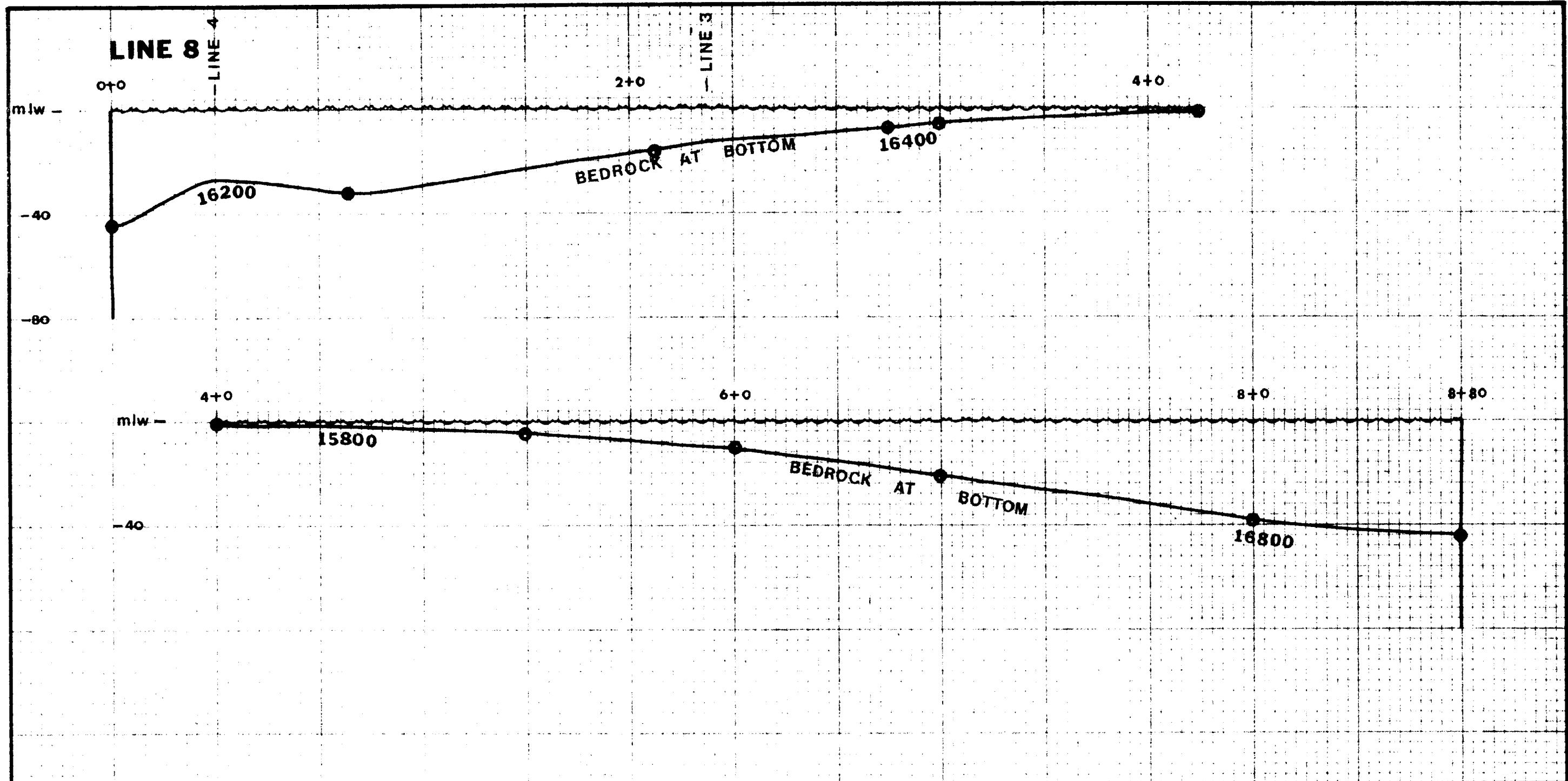
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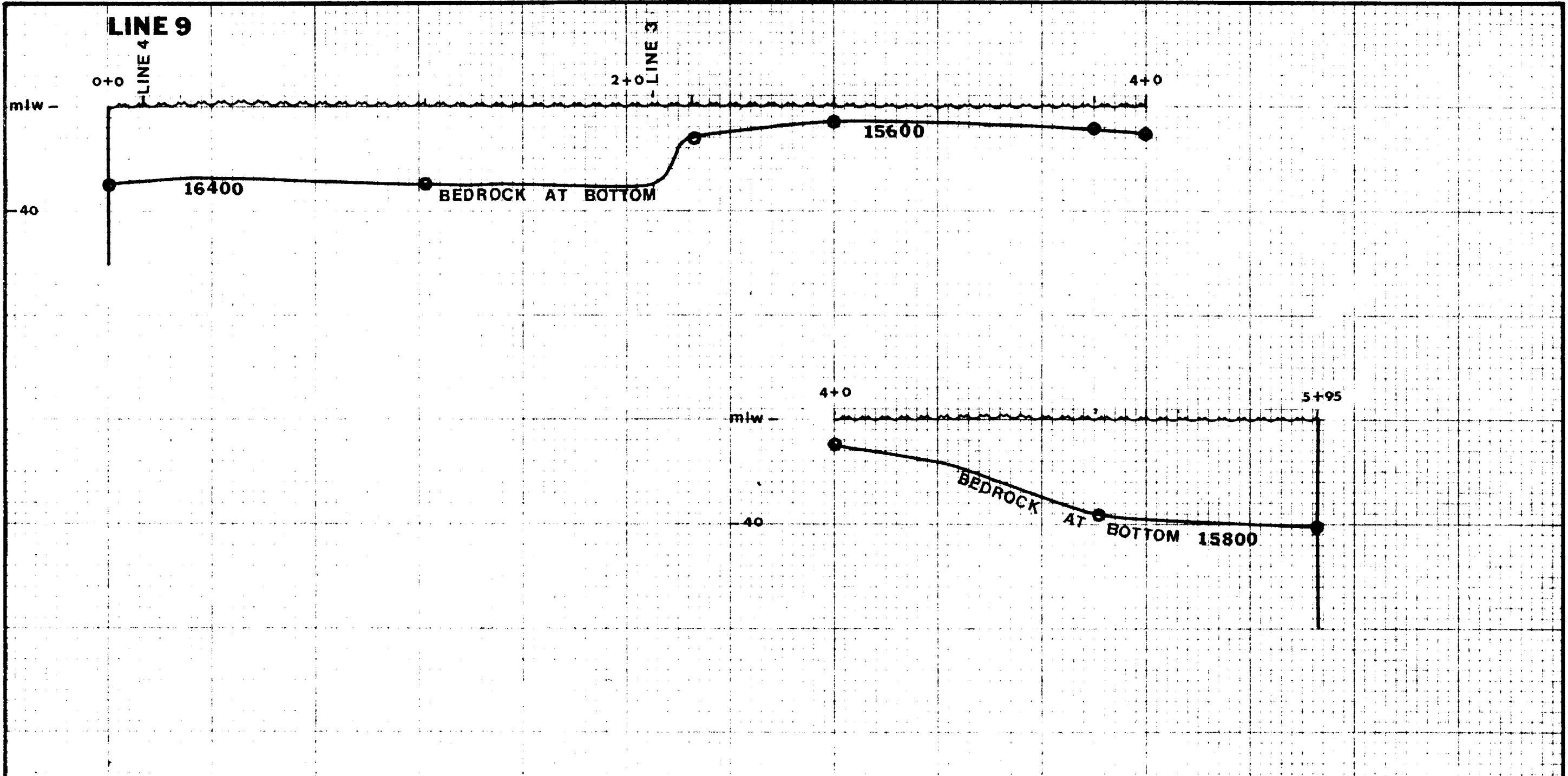
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VELOCITY BOUNDARIES

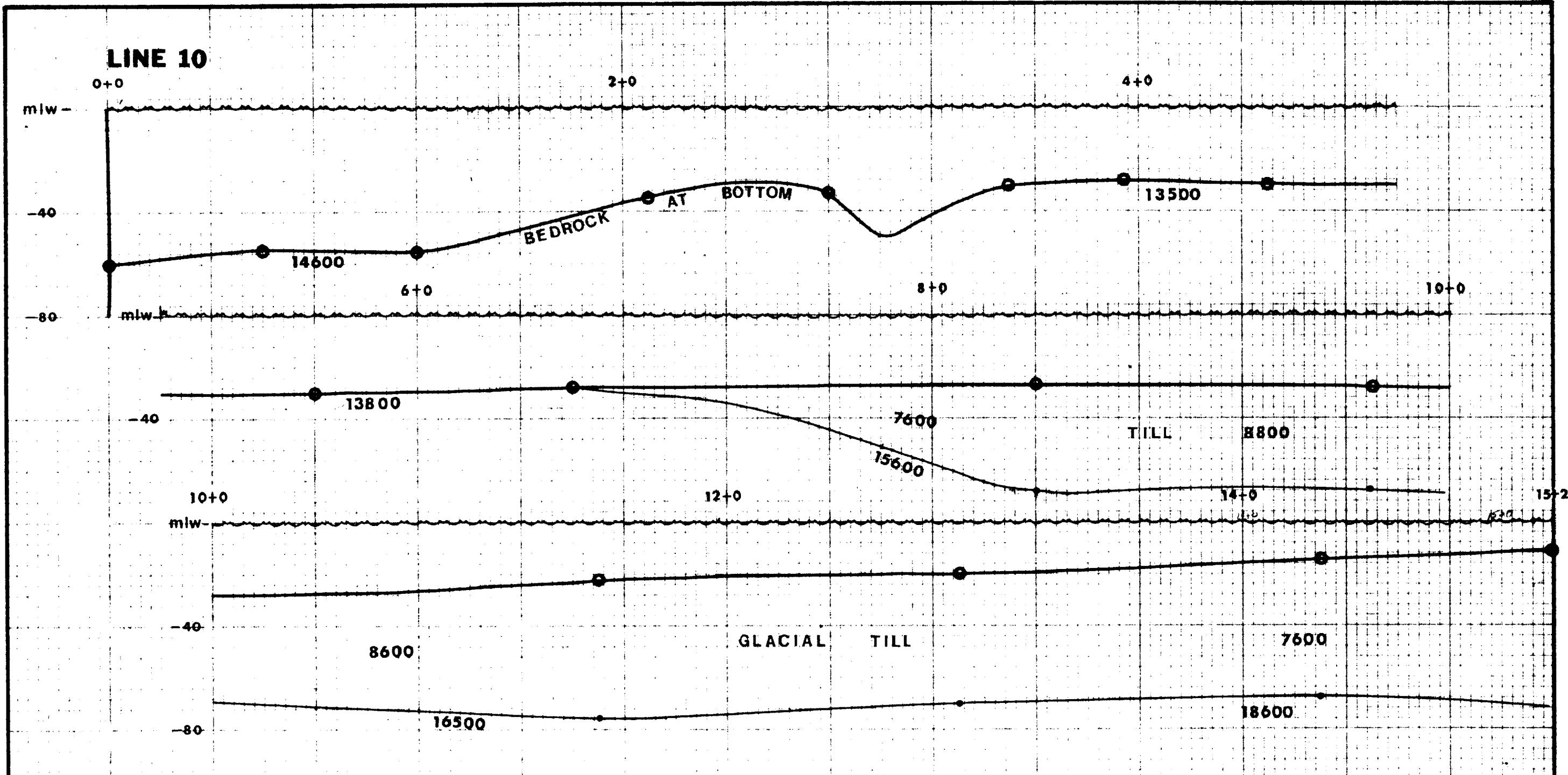
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10200

VELOCITY BOUNDARIES

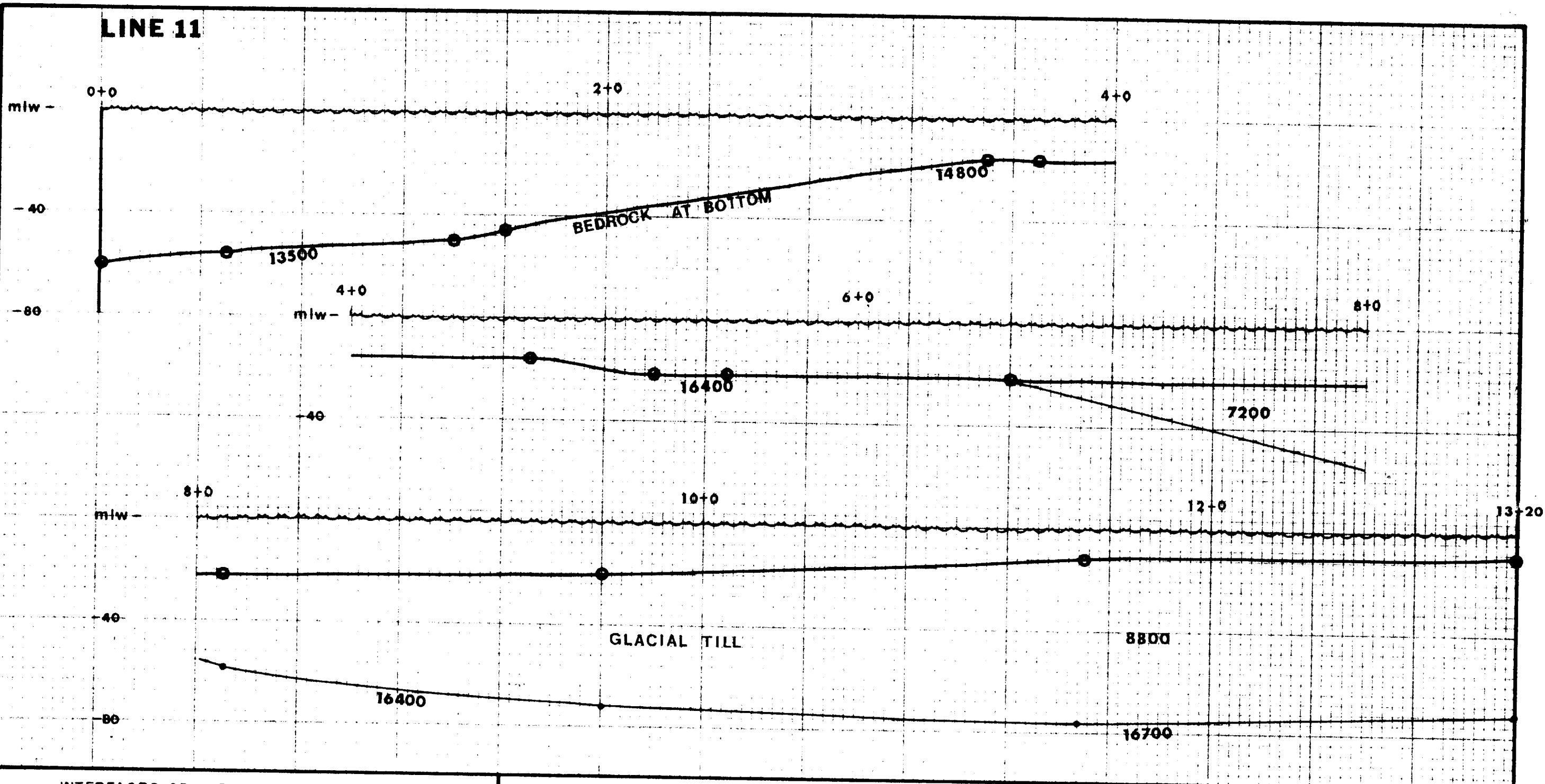
SEISMIC WAVE VELOCITIES  
IN FEET PER SECOND

### Piscataqua River

SEISMIC SURVEY PROFILES  
GEOPHYSICAL SERVICES DEPARTMENT

S.A. ALSUP ASSOC.  
Waban, Mass.

FILE NO. 7760

**LINE 11**

INTERFACES OR INFERRED INTERFACES BETWEEN SEISMIC VELOCITY ZONES ON THE FIGURES ABOVE ARE BASED UPON THE RESULTS OF STANDARD GEO-PHYSICAL INTERPRETATION TECHNIQUES. DEPTHS BELOW SURFACE, VELOCITY ZONE THICKNESS, AND VELOCITIES ARE INDICATIVE OF AVERAGE CONDITIONS BENEATH THE GEOPHONE SPREAD AND SHOULD BE USED FOR PLANNING PURPOSES ONLY. ESTIMATED ACCURACY OF THICKNESSES AND DEPTHS FOR THIS SURVEY IS  $\pm 10\%$ . DEPTHS TO INFERRED SATURATED ZONES APPLY TO DEPTHS AT TIME OF SURVEY.

SCALE: VERTICAL 1"=40'  
HORIZONTAL

SHOT POINTS

1600

GEOPHONE SPREAD

4700

INFERRRED SUBSURFACE  
VELOCITY BOUNDARIES

10200

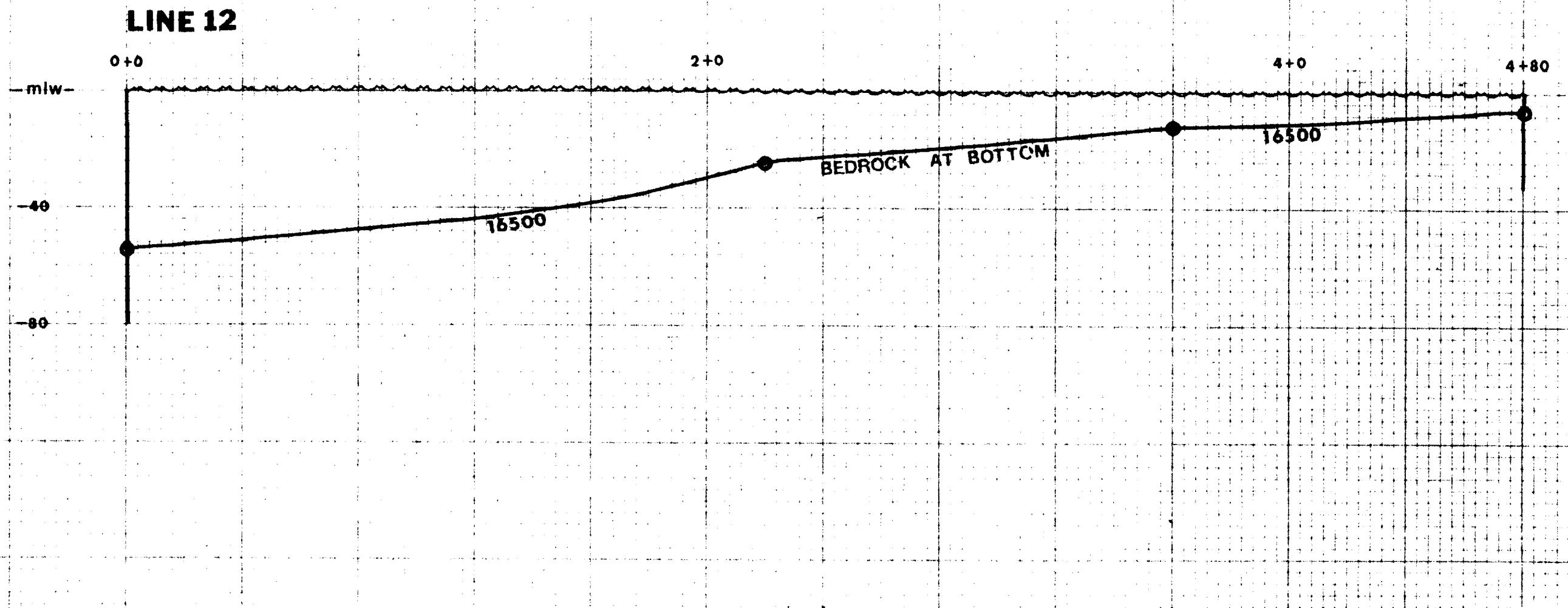
SEISMIC WAVE VELOCITIES  
IN FEET PER SECOND

**Piscataqua River**

SEISMIC SURVEY PROFILES  
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SCALE: VERTICAL 1"=40'  
HORIZONTAL

SHOT POINTS —————— 1600  
GEOPHONE SPREAD —————— 4700  
INFERRED SUBSURFACE  
VELOCITY BOUNDARIES —————— 10200  
SEISMIC WAVE VELOCITIES  
IN FEET PER SECOND

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